Crystallography of Sartorite from Binn.

(*With Plate V.*)

By Charles O. Trechmann, Ph.D., F.G.S.

[Read June 12, 1906.]

Literature[1].

G. vom Rath, 'Mineralogische Mittheilungen (Fortsetzung III): II. Skleroklas.' Ann. Chem. Phys. (Poggendorff), 1864, vol. cxxii, pp. 380-387.

H. Baumhauer, 'Ueber den Skleroklas von Binn.' Sitzungsber. k. preuss. Akad. Wiss. Berlin, 1895, pp. 243-252.

R. H. Solly, 'Sulpharsenites of lead from the Binnenthal.' Min. Mag., 1900, vol. xii, pp. 282–297 (Sartorite on pp. 286 and 297). Translation in Zeits. Kryst. Min., 1891, vol. xxxv, pp. 321–344.

W. J. Lewis, 'A large crystal of sulpharsenite of lead from the Binnenthal.' Min. Mag., 1903, vol. xiii, p. xxxiv. (Analysis by H. Jackson.)

R. H. Solly, 'On sartorite . . . and other minerals from the Binnenthal.' Min. Mag., 1904, vol. xiv, p. xx. (Title only; abstract, giving angular elements, in 'Nature,' 1903, vol. lxix, p. 142.)

H. Baumhauer, 'Die Mineralien des Binnenthals.' Bull. Murithienne, Soc. valais. sci. nat., 1905, p. 35-49.

THE mineral sartorite (of Dana) or scleroclase (of v. Waltershausen) appears to have been found much more frequently in latter years in the well-known dolomite at the Lengenbach, in the Binnenthal, Switzerland, than was formerly the case, and it may now be considered to be one of the commonest of the group of sulpharsenites of lead which have made this locality famous. Large, detached, longitudinally striated, prismatic crystals, mostly devoid of terminal faces, have been especially frequent, the majority of which are doubtless sartorites.

Notwithstanding this abundance of material, there still exists some doubt respecting the system in which this mineral crystallizes. This is due to the peculiar development of a large proportion of the crystals, which are heavily striated and grooved in one direction, and without

[1] A more complete list of the earlier references is given by R. H. Solly, Min. Mag., 1900, vol. xii, p. 282.

terminal faces, both ends of the crystal being attached to the dolomite matrix. When, in rarer cases, terminal faces are developed they appear brilliant, smooth, and unstriated, but all belonging to a single zone perpendicular to the striated one, thus affording no assistance towards a determination of the parameters. When pyramidal faces are present, which is exceedingly rare, they are frequently rounded or poorly developed on larger crystals, and on small ones either too minute, or situated in such a position with respect to the matrix that a removal of the crystal is practically impossible, owing to its extreme brittleness.

The latest detailed investigation of sartorite is due to Baumhauer (1895), who examined four crystals and determined on them a series of new forms. He enumerates a total of fifty-nine observed forms, among which are thirteen pyramids, though, as he himself states, a few of them are somewhat uncertain. Baumhauer describes, in agreement with the earlier investigation of vom Rath, this mineral as crystallizing in the orthorhombic system, though, as pointed out by himself, many of the forms only appear as single faces, whilst others exhibit very high and complicated indices.

The chemical composition is further elucidated by the analyses published by Solly (1900). These were made by Jackson on carefully selected crystals measured by the former, and lead to the assumption of the same formula as that adopted by vom Rath, viz. $PbS . As_2S_3$. A later analysis by Jackson (Lewis, 1903) also agrees closely with this formula, whilst Baumhauer, from an analysis made by König, is led to the formula $3(PbS . As_2S_3) + 2PbS . As_2S_3$.

The specific gravity, viz. 4·98 Solly, 5·05 Baumhauer, and 5·393 v. Waltershausen (cf. v. Rath), also shows some discrepancy. Solly (1903) further states that sartorite crystallizes, not in the orthorhombic, but in the monoclinic system, with the elements:

$$\beta = 88^\circ 31', \ (100):(101) = 54^\circ 45', \text{ and } (010):(111) = 69^\circ 52\tfrac{1}{2}'.$$

These data I have, however, been unable to harmonize with my own results.

On the occasion of a visit to the Binnenthal in August, 1904, I spent a day in company of Mr. Solly, with the men who work the dolomite quarry. A blasting shot was fired, and among other minerals a considerable number of specimens of sartorite were found, one or two of them exhibiting pyramidal faces. Among these and other purchased specimens were two which attracted attention on account of the brilliancy and perfection of form of small, presumably sartorite, crystals which they contained. These crystals form the principal subject of the following investigation.

The first specimen, about 4 cm. and 3 cm. in size, consisted of the usual white, granular dolomite, with some yellowish, coarser grained dolomite, some quartz, and a vein of massive sartorite, together with small crystals of realgar, pyrites, and a couple of minute binnites. In a small cavity was a crystal of sartorite of less than 2 mm. in size, on which a number of broad, smooth and highly polished faces were visible, developed in two zones perpendicular to each other, and on one corner, partially hidden by the matrix, a number of distinct pyramidal planes could be observed.

The second specimen, of similar size and component minerals with the exception of the realgar, also exhibited a small cavity in which, attached directly to the dolomite, was a group of three crystals. This group I was fortunately able to remove without fracture. It consisted of a doubly terminated sartorite about 2 mm. long and 1 mm. in each of the other dimensions, to which was attached a slightly smaller and shorter crystal of the same mineral, in what appeared to be a twinned position at an angle of about 45°, but in such a manner that the zone of the terminal faces of the second crystal was perpendicular to the same zone of the larger crystal. To the smaller crystal was attached a third crystal, at an indeterminate angle, which appeared to be rathite. The two sartorite crystals are distinguished by a beautifully developed series of terminal faces.

In the removal of the crystal of sartorite from the first specimen great care was exercised in the endeavour to obtain it unfractured; nevertheless, at the last moment, it broke, with an audible explosion, into several pieces. Very fortunately, however, the largest piece consisted of the greater part of the crystal, which had been visible on the matrix, and represented a practically complete individual. A second, smaller fragment consisted of an almost complete twinned crystal. The exact relative position of the larger to the smaller crystal was unfortunately not determinable, as the second crystal, while on the matrix, was hidden from view. It is, however, very probable that they were attached parallel to each other. These two crystals are referred to below as No. 1 and No. 2 respectively; the doubly terminated crystal from the second specimen as No. 3, and the one attached to it, in an apparently twinned position, is called No. 4. Nos. 5, 6, and 7 were received later.

The preliminary examination of Nos. 1 and 2, which are both under

1 mm. in size, was made with the aid of a Zeiss-Greenough binocular microscope—a most efficient instrument for the purpose—and powers of 35 to 65 diameters, with the result that both crystals exhibited a conspicuous monoclinic habit, which I have endeavoured to reproduce as closely as possible after nature in figs. 1 and 3, plate V, in orthogonal projection on the plane of symmetry. Figs. 2 and 4 are meant to illustrate the same crystals in an ideal development, in order to show the zonal relationship of the faces to each other. The orthodomes therefore represent the macrodomes of the orthorhombic interpretation, and the prisms those of the brachydomes. The former, as the measurements indicated, were only found in single faces, whilst the latter usually appeared in symmetrical pairs in adjacent quadrants. A striking feature on crystal No. 1 was the extraordinarily rich development of the pyramidal faces, in which the negative hemipyramids in the two opposite octants largely exceed the positive ones in number, a relationship which is reversed in crystal No. 2. It is also worthy of note that many of the combination-edges of the pyramid-faces to each other and to the prism-faces incline considerably from right to left, being all parallel with each other in the projection. The feature, however, which gives the strongest monoclinic character to these two crystals is the presence of a number of distinct twin-lamellae, quite similar to, though narrower than, those so well known on jordanite, which traverse the pyramid- and clinodome-faces from top to bottom of the crystals, parallel to the orthopinacoid, but which are invisible on the prism-faces. The latter feature would seem to exclude the possibility of the anorthic system for these crystals. The majority of these twin-lamellae have been indicated on figs. 1 and 3 by dotted lines, and it will be noticed that in both crystals they appear in greatest number towards the central portion of the crystal, and that the outlying faces, i. e. those nearest to the orthopinacoids, are in some cases quite devoid of them. In harmony with this feature is the complete and undisturbed development of the large, smooth, and brilliant orthodome faces in the vicinity of *a* (100), and a considerable striation and grooving of the same faces nearer to *c* (001). This is not so apparent on the other side of the crystal around *a′* ($\bar{1}00$), where the crystal was closely invested by the matrix; here there is a considerable striation of the orthodomes and a repetition with *a′*. The face *a* (100) is narrow, but well developed, giving a very satisfactory reflection on the goniometer. *a′* ($\bar{1}00$) is larger, but terraced by repetition. The large orthodome- and the principal prism-faces are perfectly even and highly polished and give perfect

reflections. The pyramid- and clinodome-faces, under a certain reflective angle of the light, appear slightly etched and velvety in appearance, but give, notwithstanding their minute dimensions, exceedingly good undisturbed reflections, which are very slightly affected by the faint secondary reflections of the twin-lamellae. The combination-edges of the various pyramids with one another and with the prisms and orthodomes are usually rounded and with a fused-like appearance, whilst those of the larger orthodomes and prisms are sharp and linear. The basal pinacoid *c* (001) was narrow, striated, and repeated, and unsuited for exact measurement, and the clinopinacoid *b* (010) was very narrow and rounded. Attached to the lower end of crystal No. 1 (see fig. 1) there remained a fragment of another crystal, marked II, which, according to the two well-developed orthodome-faces 2*d* ($\bar{2}01$) and $\frac{8}{3}d$ ($\bar{8}03$), represents a second individual in twinned position to the main crystal, and which would therefore form with the main crystal a contact or juxtaposition-twin on the same law as the twin-lamellae, viz. twin-plane *a* (100), but with the composition-plane perpendicular to the same. The two small visible pyramid-faces indicated on the figure were not elucidated.

Crystal No. 1 was measured through in almost all directions where zones could be followed, with the result that the monoclinic habit was distinctly confirmed, in harmony with the general appearance as already described. The measurements of the pyramid-faces, on account of their minute size and the rather weak, though distinct, reflections, were not used for fundamental angles, for which the very best reflections of the orthodomes and prisms were utilized. After some preliminary calculations, the following angles were selected for the determination of the parameters:

$$a : -d = (100) : (101) = \infty \overline{\mathrm{P}} \infty : - \overline{\mathrm{P}} \infty = 40^\circ 24\tfrac{1}{2}'$$
$$a' : \quad d = (\bar{1}00) : (\bar{1}01) = \infty \overline{\mathrm{P}} \infty : \overline{\mathrm{P}} \infty = 53^\circ 25'$$
$$a : \quad f = (100) : (110) = \infty \overline{\mathrm{P}} \infty : \infty \mathrm{P} = 51^\circ 16'$$

From which were calculated:

$$a : b : c = 1{\cdot}27552 : 1 : 1{\cdot}19487 ;$$
$$\beta = 77^\circ 48'.$$

The prisms therefore correspond to brachydomes of vom Rath and the orthodomes to his macrodomes, and I have retained the same letters for the generalized symbols of these forms, viz. *f* for the prisms and *d* for the orthodomes, to facilitate a comparison with the previous descriptions and figures of this mineral.

The axes $a : b : c$ selected by me furthermore correspond to the axes $c : b : a$ of vom Rath, with the distinction that my axes a and c are about twice as long as vom Rath's axes, which are $a : b : c = 0{\cdot}539 : 1 : 0{\cdot}619$, whereby a system of axes of almost equal length has been obtained.

From this set of parameters I have calculated the indices of all the forms which were observed with reasonable certainty on crystals Nos. 1 and 2, and which are enumerated in Table I, together with the observed and calculated angles, the quality of the measurement, such as v. g. (very good), ca. (circa), &c., the number of observations of each face, and the nature of the face.

On the two crystals were observed 87 forms, consisting of the 3 pinacoids, 17 prisms, 6 clinodomes, 19 positive and 7 negative hemi-orthodomes, 35 pyramids, divided into 16 positive and 19 negative hemipyramids. Of the orthodomes only the following four pairs have corresponding indices in the positive and negative octants: $\pm 4d$, $\pm \frac{4}{3}d$, $\pm d$, and $\pm \frac{2}{7}d$. The eight pairs of pyramids with corresponding indices in the positive and negative octants are the following:

$$\left.\begin{array}{l} e = \bar{1}11 \\ r = 111 \end{array}\right\} \pm P \qquad \left.\begin{array}{l} v = \bar{2}41 \\ q = 241 \end{array}\right\} \pm 4\grave{P}2$$

$$\left.\begin{array}{l} \gamma = \bar{4}41 \\ o = 441 \end{array}\right\} \pm 4P \qquad \left.\begin{array}{l} \tau = \bar{3}22 \\ n = 322 \end{array}\right\} \pm \tfrac{3}{2}P\tfrac{3}{2}$$

$$\left.\begin{array}{l} h = \bar{1}22 \\ p = 122 \end{array}\right\} \pm \grave{P}2 \qquad \left.\begin{array}{l} x = \bar{2}11 \\ \nu = 211 \end{array}\right\} \pm 2\bar{P}2$$

$$\left.\begin{array}{l} g = \bar{2}43 \\ \mu = 243 \end{array}\right\} \pm \tfrac{4}{3}\grave{P}2 \qquad \left.\begin{array}{l} \pi = \bar{7}22 \\ V = 722 \end{array}\right\} \pm \tfrac{7}{2}\bar{P}\tfrac{7}{2}$$

At the end of Table I are added four further prisms, which were not observed on crystals Nos. 1 and 2. On none of the seven measured crystals was there found any indication of a plane at 90° to a (100), which would correspond with vom Rath's macropinacoid.

Crystal No. 2 requires a somewhat more detailed description. It was very small, barely $\frac{2}{3}$ mm. in the direction of the b axis, $\frac{1}{3}$ mm. in the a, and $\frac{1}{2}$ mm. in the c axis, and in habit very different from No. 1. The orthodome-zone was badly developed, much striated, and repeated, with very few distinct reflections. The orthopinacoid a (100) was very minute and curved, and the basal pinacoids c (001) were narrow, striated, and repeated, with poor reflections. The pyramid-faces were, however, smooth and polished, with rounded combination-edges, and

TABLE I.

LIST OF THE FORMS OBSERVED ON CRYSTALS No. 1 AND No. 2; WITH THE OBSERVED AND CALCULATED ANGLES.

No.	Letter or Symbol.	Indices.		Crystal.		Angles							Number of Measured Angles.	Remarks.
						to $a = 100$.			to other faces.					
		Miller.	Naumann.	No. 1.	No. 2.	Calculated.	Measured.	Value.	Face.	Calculated.	Measured.	Value.		
Pinacoids :—						° ′	° ′			° ′	° ′			
1	a	100	$\infty \bar{P} \infty$	+	+	0 0								good face.
2	b	010	$\infty \breve{P} \infty$	+		90 0	90 4	ca.					1	very narrow, curved.
3	c	001	$0 P$	+	+	77 48	77 44 77 37	fair ca.					4	very narrow, uneven.
Prisms :—														
4	$20\bar{f}$	20.1.0	$\infty \bar{P} 20$		+	3 34	3 34	ca.					1	very narrow.
5	$5\bar{f}$	510	$\infty \bar{P} 5$	+	+	14 0	13 53 14 2	ca. ca.					2	narrow.
6	$\frac{9}{2}\bar{f}$	920	$\infty \bar{P} \frac{9}{2}$	+		15 29	15 29	fair					1	good.
7	$4\bar{f}$	410	$\infty \bar{P} 4$	+		17 19	17 8	g.					1	good.
8	$\frac{7}{2}\bar{f}$	720	$\bar{P} \frac{7}{2}$	+		19 36	19 31 19 33	g. g.					2	narrow, distinct.
9	$3\bar{f}$	310	$\infty \bar{P} 3$		+	22 34	21 35	g.					1	narrow, distinct.
10	$\frac{11}{4}\bar{f}$	11.4.0	$\infty \bar{P} \frac{11}{4}$		+	24 23	24 38	g.					1	narrow, distinct.
11	$\frac{5}{2}\bar{f}$	520	$\infty \bar{P} \frac{5}{2}$	+		26 30	26 30	v.g.					2	large, good.
12	$\frac{9}{4}\bar{f}$	940	$\infty \bar{P} \frac{9}{4}$	+		28 59	29 0	ca.					1	narrow.
13	$2\bar{f}$	210	$\infty \bar{P} 2$	+	+	31 56	31 54	v.g.					2	large and smooth.
14	$\frac{11}{7}\bar{f}$	11.7.0	$\infty \bar{P} \frac{11}{7}$		+	38 26	38 18	fair					1	good.

TABLE I (*continued*).

15	$\frac{3}{2}\bar{f}$	320	$\infty\bar{P}\frac{3}{2}$	+	+	39 44	39 44 39 48	v.g. v.g.	001	80 39	80 32	g.	3	large and smooth.
16	$\frac{4}{3}\bar{f}$	430	$\infty\bar{P}\frac{4}{3}$		+	43 5	42 55	g.					1	narrow, distinct.
17	f	110	∞P	+	+	Fund. ∡	51 16	v.g.	001	82 24	82 31	g.	3	large and smooth.
18	$2\grave{f}$	120	$\infty\grave{P}2$	+	+	68 9	68 2 68 4	ca. ca.	001	85 29	85 33	g.	3	very narrow.
19	$3\grave{f}$	130	$\infty\grave{P}3$		+	75 2	75 48	ca.					1	very narrow, doubtful.
20	$\frac{13}{2}\grave{f}$	2.13.0	$\infty\grave{P}\frac{13}{2}$	+		82 58	82 56	ca.					1	very narrow.
Clinodomes :—														
21	a	023	$\frac{2}{3}\grave{P}\infty$	+		80 24			001	37 54	37 57	ca.	1	minute.
22	κ	045	$\frac{4}{5}\grave{P}\infty$	+		81 7			001	43 3	43 3	v.g.	1	distinct.
23	i	011	$\grave{P}\infty$	+		82 6	82 3	g.	001	49 26	49 23	g.	1	distinct.
24	y	065	$\frac{6}{5}\grave{P}\infty$	+		82 57			001	54 29	55 0	g.	1	minute, uneven.
25	l	085	$\frac{8}{5}\grave{P}\infty$	+		84 17			001	61 51	61 45	ca.	1	minute.
26	w	041	$4\grave{P}\infty$	+		87 28	87 37	ca.	001	77 55	78 7	ca.	1	long and narrow.
Orthodomes, positive :—														
27	$9d$	$\bar{9}01$	$9\bar{P}\infty$	+		6 46	6 53	ca.					1	very narrow.
28	$8d$	$\bar{8}01$	$8\bar{P}\infty$	+		7 39	7 38	fair					1	distinct, striated.
29	$\frac{9}{2}d$	$\bar{9}02$	$\frac{9}{2}\bar{P}\infty$	+		13 43	13 50	v.g.					1	good and smooth.
30	$\frac{21}{5}d$	$\overline{21}.0.5$	$\frac{21}{5}\bar{P}\infty$	+		14 43	14 48	fair					1	distinct.
31	$4d$	$\bar{4}01$	$4\bar{P}\infty$	+	+	15 27	15 29	v.g.					3	large and smooth.
32	$\frac{8}{3}d$	$\bar{8}03$	$\frac{8}{3}\bar{P}\infty$	+		23 9	23 10	g.					1	fair, disturbed.
33	$\frac{5}{2}d$	$\bar{5}02$	$\frac{5}{2}\bar{P}\infty$		+	24 39	25 2	fair					1	narrow, distinct.
34	$2d$	$\bar{2}01$	$2\bar{P}\infty$	+		30 27	30 35 30 27 30 29	fair v.g. g.					3	large and smooth.

TABLE I (*continued*).

No.	Letter or Symbol.	Indices.		Crystal.		Angles							Number of Measured Angles.	Remarks.
						to a = 100.			to other faces.					
		Miller.	Naumann.	No. 1.	No. 2.	Calculated.	Measured.	Value.	Face.	Calculated.	Measured.	Value.		
Orthodomes, positive (*continued*) :—						° ′	° ′			° ′	° ′			
35	$\frac{9}{5}d$	$\bar{9}05$	$\frac{9}{5}\bar{P}\infty$	+	+	33 32	34 14 34 0 34 1	fair do. do.					3	very narrow.
36	$\frac{8}{5}d$	$\bar{8}05$	$\frac{8}{5}\bar{P}\infty$	+		37 12	37 9	fair					1	narrow, distinct.
37	$\frac{3}{2}d$	$\bar{3}02$	$\frac{3}{2}\bar{P}\infty$		+	39 18	40 35	fair					1	small, distinct.
38	$\frac{4}{3}d$	$\bar{4}03$	$\frac{4}{3}\bar{P}\infty$	+		43 17	43 27	ca.					1	very narrow.
39	$\frac{5}{4}d$	$\bar{5}04$	$\frac{5}{4}\bar{P}\infty$	+	+	45 32	45 43 45 26	fair do.					3	very narrow.
40	d	$\bar{1}01$	$\bar{P}\infty$	+	+	Fund. ✗	53 25	v.g.					4	distinct and smooth.
41	$\frac{19}{20}d$	$\overline{19}.0.20$	$\frac{19}{20}\bar{P}\infty$		+	55 14	55 22	fair					1	distinct, striated.
42	$\frac{7}{10}d$	$\bar{7}.0.10$	$\frac{7}{10}\bar{P}\infty$	+		65 33	65 2	ca.					1	very narrow.
43	$\frac{2}{3}d$	$\bar{2}03$	$\frac{2}{3}\bar{P}\infty$		+	67 5	66 45	fair					1	very narrow.
44	$\frac{4}{7}d$	$\bar{4}07$	$\frac{4}{7}\bar{P}\infty$	+	+	71 40	71 55 71 44	fair ca.					2	narrow, striated.
45	$\frac{2}{7}d$	$\bar{2}07$	$\frac{2}{7}\bar{P}\infty$		+	86 42	86 47	fair					1	narrow, rough.
Orthodomes, negative :—														
46	$-4d$	401	$-4\bar{P}\infty$	+		13 52	13 34	fair					1	narrow, distinct.
47	$-\frac{4}{3}d$	403	$-\frac{4}{3}\bar{P}\infty$	+	+	33 48	33 53 33 51	v.g. fair					2	large, striated.
48	$-\frac{7}{6}d$	706	$-\frac{7}{6}\bar{P}\infty$			36 51	36 42	fair					1	narrow, distinct.

TABLE I (*continued*).

49	$-d$	101	$-\bar{P}\infty$	+	+	Fund ∡	40 24$\frac{1}{3}$	v.g.					3	large broad face, good.
50	$-\frac{11}{12}d$	11.0.12	$-\frac{11}{12}\bar{P}\infty$	+		42 25	42 25	fair					1	narrow, striated.
51	$-\frac{3}{4}d$	304	$-\frac{3}{4}\bar{P}\infty$	+		46 55	46 1	ca.					1	very narrow, indistinct.
52	$-\frac{2}{7}d$	207	$-\frac{2}{7}\bar{P}\infty$		+	63 45	64 20	fair					1	distinct.
Pyramids:—														
53	e	$\bar{1}11$	P	+	+	64 32	64 35 64 22	ca. fair	110	35 59	35 55 35 59	fair	2	small, distinct.
54	γ	$\bar{4}41$	4 P		+	52 12			110	9 36	9 43	g.	1	small, distinct.
55	ρ	113	$-\frac{1}{3}$ P		+	63 33			110	57 31	57 4	ca.	1	very small.
56	Δ	445	$-\frac{4}{5}$ P	+		54 36			110	36 42	36 48	g.	1	very small, distinct.
57	r	111	$-$P	+	+	52 59	52 59 53 2 53 3	g. ca. v.g.	110	31 19	31 20 31 8 31 26	fair g. g.	3	small, good.
58	m	443	$-\frac{4}{3}$ P		+	51 32			110	24 58	24 47 24 55 24 58	g. fair do.	3	small, distinct.
59	z	221	-2 P		+	50 32			110	17 36	17 9	ca.	1	very small, curved.
60	o	441	-4 P	+	+	50 20	50 29	g.	110	9 12	9 9 9 9	fair g.	3	small, distinct.
61	H	$\bar{3}44$ or 799	$\grave{P}\frac{4}{3}$ or $\grave{P}\frac{9}{7}$		+	72 7 71 14	71 7	ca.					1	small, narrow, distinct.
62	δ	$\bar{1}66$	$\grave{P}6$	+		92 5	92 3	ca.					1	very small.
63	u	$\bar{1}23$	$\frac{2}{3}\grave{P}2$	+	+	85 23			120	52 40	52 30 52 48	ca. ca.	3	very small.
64	ϵ	$\bar{2}45$	$\frac{4}{5}\grave{P}2$	+	+	83 6			120	47 3	47 1 47 3	fair v.g.	3	small, distinct.
65	h	$\bar{1}22$	$\grave{P}2$	+	+	80 25	80 6 80 24	g. g.	120	40 12	40 8 40 12	g. g.	3	large and distinct.
66	g	$\bar{2}43$	$\frac{4}{3}\grave{P}2$		+	77 20			120	31 56	31 54	g.	1	small, distinct.

TABLE I (*continued*).

No.	Letter or Symbol.	Indices.		Crystal.		Angles to $a = 100$			Angles to other faces.				Number of Measured Angles.	Remarks.
		Miller.	Naumann.	No. 1.	No. 2.	Calculated.	Measured.	Value.	Face.	Calculated	Measured.	Value.		
						° ′	° ′			° ′	° ′			
67	*β*	$\bar{1}21$	$2\grave{\mathrm{P}}2$		+	74 0			120	22 14	22 14	g.	1	small, distinct.
68	*B*	$\bar{4}83$	$\frac{8}{3}\grave{\mathrm{P}}2$		+	72 22			120	16 55	17 3	ca.	1	very small.
69	*v*	$\bar{2}41$	$4\grave{\mathrm{P}}2$	+		70 48	70 41		120	11 22			1	narrow, distinct.
70	*p*	122	$-\grave{\mathrm{P}}2$	+		65 57	65 55	g.	120	36 43	36 44	ca.	2	large, distinct.
71	*A*	5·10·8	$-\frac{5}{4}\grave{\mathrm{P}}2$	+		65 36			120	31 7	30 31	ca.	1	very narrow.
72	*μ*	243	$-\frac{4}{3}\grave{\mathrm{P}}2$		+	65 33			120	29 34	29 33	fair	1	very small, distinct.
73	*q*	241	$-4\grave{\mathrm{P}}2$	+		66 24	66 58	g.	120	11 2	10 56	g.	1	small, distinct.
74	*x*	$\bar{2}11$	$2\bar{\mathrm{P}}2$		+	42 30	42 23	fair					1	very small, distinct.
75	*ν*	211	$-2\bar{\mathrm{P}}2$	+		36 9	36 6	g.					1	small, distinct.
76	*D*	$\bar{6}41$	$6\bar{\mathrm{P}}\frac{3}{2}$		+	41 25			320	7 52	7 58	fair	1	small, distinct.
77	*σ*	645	$-\frac{6}{5}\bar{\mathrm{P}}\frac{3}{2}$	+		45 21			320	31 17	30 56	ca.	1	very small, doubtful.
78	*s*	643	$-2\bar{\mathrm{P}}\frac{3}{2}$	+	+	41 24			320	20 47	20 35 / 21 3	g. / ca.	2	large, distinct.
79	*t*	321	$-3\bar{\mathrm{P}}\frac{3}{2}$	+		39 58			320	14 30	14 13	fair	1	small, distinct.
80	*Y*	21·14·3	$-7\bar{\mathrm{P}}\frac{3}{2}$		+	39 17			320	6 29	6 35	ca.	1	long and very narrow, curved.

TABLE I (*continued*).

81	τ	322	$\frac{3}{2}\bar{P}\frac{3}{2}$		+	51 54	51 48	v.g.	320	30 39	30 38	v.g.	1	large and smooth.
82	π	722	$\frac{7}{2}\bar{P}\frac{7}{2}$	+		26 24	26 32	ca.					1	very narrow.
83	η	611	$6\bar{P}6$	+		15 43	15 5	ca.					1	very narrow, doubtful.
84	n	322	$-\frac{3}{2}\bar{P}\frac{3}{2}$	+	+	43 18	43 22 43 23 43 13	v.g. fair g.	320	26 23	26 25 26 22	g. ca.	3	large, very good.
85	V	722	$-\frac{7}{2}\bar{P}\frac{7}{2}$	+		23 35	24 25	ca.					1	very small, doubtful.
86	N	411	$-4\bar{P}4$	+		21 3	21 47	ca.					1	very small, doubtful.
87	C	12.1.1	$-12\bar{P}12$	+		7 34	7 28	ca.					1	very small, doubtful.

Prisms, observed on other Crystals:

				No. 5.	No. 6.	No. 7.									
	$\frac{11}{2}\bar{f}$	11.2.0	$\infty\bar{P}\frac{11}{2}$	+			12 46	12 56	ca.					1	very narrow, striated.
	$\frac{11}{5}\bar{f}$	11.5.0	$\infty\bar{P}\frac{11}{5}$			+	29 32	29 28	fair					1	narrow, distinct.
	$\frac{5}{4}\bar{f}$	540	$\infty\bar{P}\frac{5}{4}$		+	+	44 55	44 48	v.g.					2	broad, good.
	$4\grave{f}$	140	$\infty\grave{P}4$	+		+	78 40	78 36	g.					2	broad, good.

traversed, exactly as in No. 1, with many twin-lamellae parallel to *a* (100), of which the most prominent are indicated in fig. 3 by dotted lines. The prism-faces were also smooth and brilliant, but very small and repeated, thus obscuring the zones, which were so clear and prominent in No. 1. The monoclinic habit was, however, quite evident, and the twinned nature clearly indicated by the reentrant angle of the basal pinacoids. On account of the inferior development of leading planes, it was found impossible to unravel this crystal, until the complete calculations on No. 1 had been made, and all its faces determined; it was then found that the three zones [*ueh*], [*for*], and [*nrh*] agreed in their angles with those of No. 1. Thereupon the best reflections, viz. those from the faces *h* and *f*, were utilized as a foundation for the determination of the observed faces, with the result shown on Table I, in which the measured angles agree fairly well with the calculated ones.

As is indicated in fig. 3, this crystal consists of three individuals, attached to each other on the face *a* (100) as twin-plane, in such a manner that the central individual appears inserted as a broad twin-lamella between the two exterior ones. The twinning edge is clearly developed in the upper half of the crystal between I on the right hand and II, but in the lower part, and between I on the left and II, is obscured, partly by fracture and partly by a very small protruding crystal in the position I. The faces h, ϵ, u and $\underline{h}$, $\underline{\epsilon}$, $\underline{u}$ give respectively the following (non-reentrant) angles:

$h:\underline{h}$	calculated	19°10′,	observed	19°12′
$\epsilon:\underline{\epsilon}$	„	13°47′	„	14°14′
$u:\underline{u}$	„	9°15′	„	10° 1′
$c:\underline{c}$	„	24°24′	„	24°11′

Fig. 4 is meant to represent this crystal in an ideal development, with the principal forms observed on it.

It will be noticed that the clinodomes are totally absent, and that there is a richer development of the positive hemipyramids as compared with crystal No. 1: we find 12 of them, as against 8 on No. 1, and 9 negative hemipyramids corresponding with 14 on No. 1. It is very strange that only eight pyramids are common to both crystals, viz. *e*, *r*, *o*, *u*, *ε*, *h*, *s*, and *n*, which, however, represent those with simpler indices, and belonging to the principal zones. This feature seems to be of some significance: for if such widely different sets of related forms are found on two crystals, which were originally attached to each other and probably in twinned position, then it might be expected that still wider differences would be observed on crystals from other specimens: and this may in part explain the want of agreement between the observations made on different crystals of sartorite by other investigators.

On my crystals Nos. 1 and 2 other pyramidal faces could be detected, but they defied measurement on account of their minute size, or their hidden position. In fig. 5 almost all the forms observed on crystals Nos. 1 and 2 have been represented in a stereographic projection on the plane of symmetry.

The most important question which arises out of the above observations, is whether these crystals are actually sartorite or whether they belong to some other mineral. The crystals are so small that any chemical test is out of the question; so also is a determination of the specific gravity. A distinct cleavage was nowhere observable on any of the crystals examined by me. The only means of identification remaining are the geometrical form and the streak. The latter was examined on minute fragments from crystals Nos. 1, 2, 5, and 6, and found to be practically the same with all of them, viz. reddish-chocolate, in harmony with the statement of vom Rath. On the other hand, a very similar streak is given by the related minerals dufrenoysite, rathite, and baumhauerite, so that this character is not much to be relied upon.

With respect to the geometrical form there is already a considerable diversity between the forms given by vom Rath and by Baumhauer, especially, as has been pointed out by the latter, among the macrodomes (see l. c., p. 249). On the other hand, four of the five brachydomes observed by vom Rath are repeatedly observed again by Baumhauer. On the seven crystals, which I have examined, the measurements of the orthodomes show so little similarity that I have found it impossible to harmonize them either with each other, or with those observed by vom Rath and Baumhauer. Even between the crystals Nos. 1 and 2 there is so little similarity, notwithstanding the fact that these two crystals undoubtedly belong to the same larger one, and are of the same substance, that only five positive and two negative hemiorthodomes, out of a total of twenty-six, appear on both of them.

On the crystals Nos. 3 and 4, notwithstanding the exceptionally perfect development of the prism-zone and the orthopinacoids, the orthodomes could not be determined at all, for the whole zone of these, on both crystals, gave a continuous series of grouped reflections, due to the fine striation, so that not a single individualized reflection could be noted. The crystals Nos. 5, 6, and 7 gave some very satisfactory reflections, but in no case could they with certainty be brought into harmony with the orthodomes observed on Nos. 1 and 2; even on one and the same crystal, what appeared to be corresponding faces gave very variable angles. The impression conveyed is that the faces of this zone are profoundly influenced by repeated twinning or some other as yet unexplainable cause.

Only in the prism, or brachydome, zone of all hitherto described crystals is there found an unexpected and striking similarity, which I have attempted to show on the comparative Table II. It contains the whole of the brachydomes given by vom Rath and Baumhauer and all the prisms observed on my crystals Nos. 1 to 7, together with the calculated and the principal measured angles. It will be at once noticed that the forms most frequently observed by me correspond in the angles with those most often observed by the above-named authors, and that there exists a fairly close agreement between the measured and calculated angles.

In Table III I have furthermore tabulated, for the four most frequent prisms, all my best measurements, in order to indicate the fluctuations on one and the same and on different crystals. A comparison of these results with each other and with previous observations would seem to justify the assumption that all my seven crystals actually belong to the mineral sartorite.

On the crystals Nos. 3 and 4, there was no indication of the presence of any pyramidal faces. No. 7, a well-formed crystal of the ordinary type, showed a few rounded indeterminable pyramids. Crystals No. 5 and 6 were derived from a very small specimen of dolomite, and represent the upper and lower terminations of one and the same somewhat larger crystal, the central portion of which was overlaid by a similar one, almost at right angles to it, such as has been referred to by Baumhauer (l. c., p. 251) as being possibly a twin-formation. This rectangular intergrowth of sartorite is a not uncommon occurrence. Both of these crystals have a rich development of pyramidal faces, of which forty-five were counted on No. 5 and about thirteen on No. 6. Twin-lamellae were distinctly observable on both crystals, but especially on No. 6, where some of the faces were quite devoid of them, and others were closely intersected. The zonal relations of these pyramidal faces were, however, so indistinct, and most of them were so small, that it has not been possible so far to identify them. Some measurements made on crystal No. 6 could not be harmonized with Nos. 1 and 2, nor with the pyramids observed by Baumhauer.

TABLE II.—COMPARISON OF THE OBSERVED PRISMS WITH THE BRACHYDOMES OF VOM RATH AND BAUMHAUER.

Symbol.		v. Rath & Baumh.		C.O.T.		Observed by		Number of measured edges.	C O.T. observed on Crystal No.							Number of measured edges.
		to c = 001.		to a = 100.												
C.O.T.	v. R. & B.	Calculated.	Observed	Calculated.	Observed.	v. R.	B.		1	2	3	4	5	6	7	
$20\bar{f}$				3° 34′	3° 34′					+						1
$\frac{11}{2}\bar{f}$	$\frac{4}{11}f$	12° 41′	12° 38′	12 46	12 56		$+^{2}$	2					+			1
$5\bar{f}$	$\frac{2}{5}f$	13 54½	14 2	14 0	14 2		+	2	+	+					+	3
$\frac{9}{2}\bar{f}$	$\frac{9}{20}f$	15 34	15 29	15 29	15 29		+	1	+						+	2
	$\frac{7}{15}f$	16 7	16 5				+	1 uncertain								
$4\bar{f}$	$\frac{1}{2}f$	17 12	17 16	17 19	17 8		$+^{2}$	2	+						+	2
$\frac{7}{2}\bar{f}$	$\frac{4}{7}f$	19 28	19 30	19 36	19 32		+	1	$+^{2}$				+	$+^{2}$		5
$3\bar{f}$	$\frac{2}{3}f$	22 25	22 24	22 34	21 35		$+^{2}$	2		+						1 uncertain
$\frac{11}{4}\bar{f}$				24 23	24 38					+						1
$\frac{5}{2}\bar{f}$	$\frac{4}{5}f$	26 20	26 10-20	26 30	26 30		+	2	$+^{2}$		$+^{4}$	+	$+^{2}$	$+^{2}$	+	12
	$\frac{5}{6}f$	27 17	27 6				+	1 uncertain								
$\frac{9}{4}\bar{f}$				28 59	29 0				+							1
$\frac{11}{5}\bar{f}$				29 32	29 23										+	1
	$\frac{14}{15}f$	30 0	30 1				+	1								
$2\bar{f}$	f	31 45	31 54	31 56	31 54	+	+	3	+	+				+		3
$\frac{11}{7}\bar{f}$				38 26	38 18					+						1
$\frac{3}{2}\bar{f}$	$\frac{4}{3}f$	39 31	39 41	39 44	39 44-48	+	+	5	$+^{2}$	+	$+^{4}$	+	+	$+^{7}$	+	12
	$\frac{41}{30}f$	40 14	40 15				+	1								
$\frac{4}{3}\bar{f}$	$\frac{3}{2}f$	42 52	43 28	43 5	42 55	+		1		+			+	+		3
	$\frac{47}{30}f$	44 7	44 18				+	1 uncertain								
$\frac{5}{4}\bar{f}$				44 55	44 48									+	+	2
	$\frac{17}{10}f$	46 27	46 32				+	1 uncertain								
	$\frac{26}{15}f$	47 1	47 6				+	1								
	$\frac{29}{15}f$	50 7	50 3-6				+	2								
$\grave{f}$	$2f$	51 4	51 10-14	51 16	51 16	+	$+^{5}$	7	$+^{2}$	+	$+^{4}$	$+^{2}$	$+^{2}$	+	$+^{2}$	14
$2\grave{f}$	$4f$	68 0	68 4	68 9	68 2-10	+	$+^{6}$	8	$+^{2}$	+	$+^{4}$	$+^{2}$	$+^{2}$	+	$+^{2}$	14
$3\grave{f}$				75 2	75 48					+						1 uncertain
$4\grave{f}$				78 40	78 36								+		+	2
$\frac{13}{2}\grave{f}$				82 58	82 56				+							1
b	010	90 0	90 0	90 0	90 0	+	+	2	+		$+^{2}$	+	+		+	6

TABLE III.—Fluctuations of the Angles of the Principal Prisms.

Angles to $a = 100$.

Symbol.	Indices. Miller.	Indices. Naumann.	Calculated.	Measured on Crystal No. 1	2	3	4	5	6	7
			° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
$\frac{5}{2}\bar{f}$	520	$\infty \bar{P} \frac{5}{2}$	26 30	26 30½ 18		26 25 26 16½ 37½	26 25½			26 24
$\frac{3}{2}\bar{f}$	320	$\infty \bar{P} \frac{3}{2}$	39 44	39 48	39 44	39 38 38½ 17½ 46	39 34½		39 34	39 36
f	110	∞P	51 16	51 16½ 15½	51 8	51 9½ 13½ 4 21½	51 6	51 7	51 6½	51 8 6½
$2\grave{f}$	120	$\infty \grave{P} 2$	68 9			68 10½	68 1½ 5¾	68 8		68 2½ 2½

It may be mentioned that in the determination of the orthodomes of Nos. 1 and 2 only distinct and individualized reflections were made use of; all such as were grouped or coloured were rejected, or only used to corroborate better reflections. All the measurements were made on a Fuess No. 2 horizontal-circle goniometer, with the eyepiece γ, a small angle of incidence, and a Websky slit illuminated by an incandescent gas-lamp and the condensing lens. Even the smallest pyramidal faces, owing to their brilliancy, gave distinct and individualized reflections, and may, therefore, with few exceptions, be considered as safely determined.

With less confidence would I wish it to be assumed that the crystals Nos. 1 and 2 are, beyond any doubt, to be considered as sartorites. It is not impossible that we have here to deal with a case similar to that of the humite group, in which several closely allied substances possess identical or almost identical angles in one zone, and different ones in the zone perpendicular to the first. It is also possible that such morphotropic substances may form lamellar intergrowths, and thus obscure the crystallographic properties of each other. An apparent lamellar structure is observable on fractured surfaces of sartorite, and is also visible on crystals Nos. 1 and 2.

Further observations are necessary in order to clear up the difficulties and discrepancies still attaching to even the most perfect crystals of this mineral, and it is hoped that this contribution may draw renewed attention towards it.

Explanation of Plate V.

Crystals of Sartorite from the Binnenthal, Switzerland.

Orthogonal projections on the plane of symmetry. (The dotted lines represent twin-lamellae parallel to *a* (100).)

Fig. 1.—Crystal No. 1; actual development.

Fig. 2.—The same; ideal development.

Fig. 3.—Crystal No. 2; actual development of twinned crystal.

Fig. 4.—The same; ideal development.

Fig. 5.—Stereographic projection on the plane of symmetry, showing most of the forms observed on crystals Nos. 1 and 2.

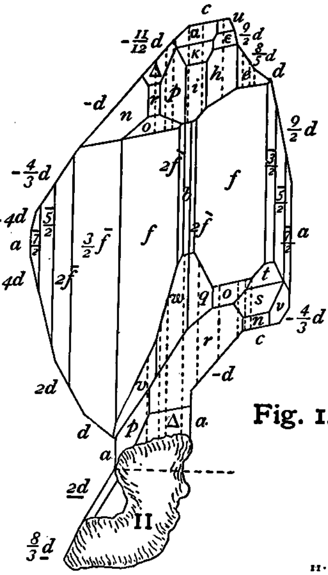

Fig. 1.

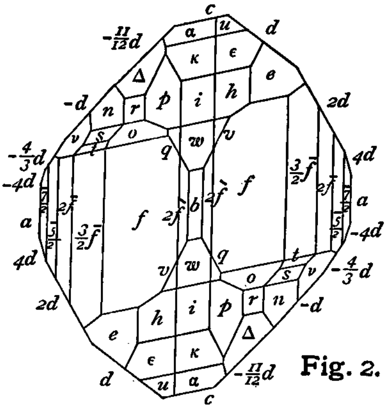

Fig. 2.

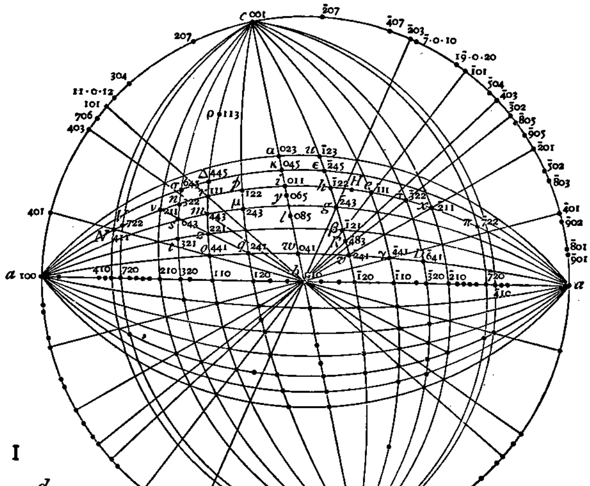

Fig. 5.

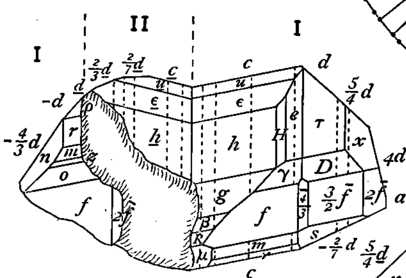

Fig. 3.

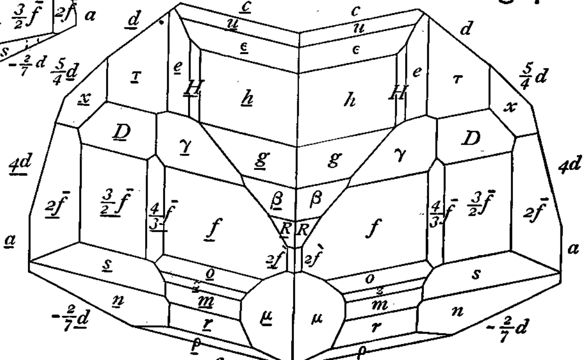

Fig. 4.

C.O.T. del. E. W. sc.